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Reply

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In my original article (Relethford, 1997), I provided evidence of a hemispheric difference in human skin color. Although the evolutionary reasons for this difference are not known, it was noted that there is evidence for a hemispheric difference in ultraviolet (UV) radiation. Several reasons, including a hemispheric difference in the earth–sun distance, were noted. Chaplin and Jablonski's comment (1998) does not dispute the hemispheric difference in skin color but argues against a hemispheric difference in UV radiation. Because their argument concerns itself with data from the field of atmospheric science, I invited Richard McKenzie, author of many of the cited papers on UV radiation, to participate in this reply.

Model calculations of clear-sky UV radiation indicate that based on recent climatologies of ozone measured from satellites, there are significant hemispheric differences in the latitudinal decreases in UV radiation. Latitude for latitude, the calculated doses are larger in the Southern Hemisphere. In annually averaged doses, the hemispheric differences in erythemally weighted (or "sunburning") UV radiation (McKinlay and Diffey, 1987) are generally less than 10%. However, for doses received during peak months (summer), the differences exceed 15% at latitudes greater than 25°. The hemispheric difference in both mean and maximum UV radiation is shown in Figure 1.

The calculated hemispheric differences arise from the lower column amounts of ozone in the Southern Hemisphere and because the time of closest approach between the earth and sun coincides with the Southern Hemisphere summer. Because of the strong solar zenith angle dependence of UV transmission, most of the annual dose of UV radiation arrives in the summer. These calculations ignore the effects of clouds and aerosols, both of which can have important effects on UV radiation.

Because of instrument intercalibration difficulties, there have been few measurements that directly quantify the magnitude of these geographical differences in UV radiation. The few measurements that have been made with cross-calibrated instruments (e.g., Seckmeyer et al., 1995 and references therein) have shown even larger hemispheric differences (40–60% in erythemal UV radiation), both for clear-sky conditions and for all-weather conditions. The larger differences are attributable in part to differences in tropospheric pollution. However, there are important sampling issues that need to be considered because there can be large geographical differences in cloud cover and pollution. It is unlikely that the measurements that have been made were at sites that were accurately representative of the whole hemisphere.

Recently, satellite data have been used to estimate global patterns of UV radiation doses, including cloud effects. Chaplin and Jablonski's analysis, in which they find smaller hemispheric differences, seems to contradict the results based on clear-sky model calculations and the direct measurements. However, Chaplin and Jablonski pre-

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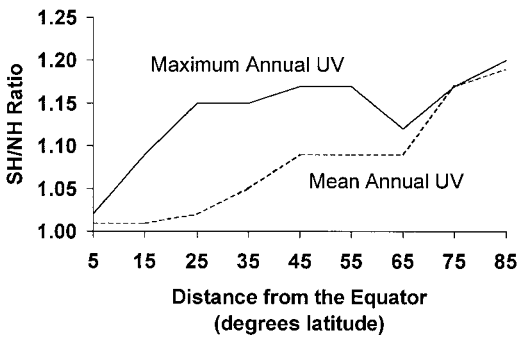

Fig. 1. Hemispheric differences in clear-sky dose of erythemal UV radiation. Monthly daily dose of erythemal UV was calculated for clear-sky conditions using a climatology of ozone measurements from the TOMS instrument from 1979 to 1992. Calculations were from the "tuv" radiative transfer code described by Madronich (1993). For each 5° interval, the annual average and maximum doses were then computed. These data were converted to ratios in this graph to show the higher levels of UV radiation in the Southern Hemisphere.

sented their results in terms of hemispheric differences (area weighted) rather than considering latitude by latitude. Because 50% of the globe lies within 30° of the equator, where the UV differences are smallest (Fig. 1), this averaging tends to minimise the differences discussed by Relethford (1997). We accept that when only land masses are considered, the habitable land mass of the Southern Hemisphere is concentrated nearer to the equator. However, this is irrelevant to the arguments put forward by Relethford, unless one assumes that the possibility of migration patterns over a wider range of latitudes can have important moderating effects on skin color. Other possible reasons for the smaller differences (compared with those for clear skies) include (1) increased effects on UV of cloud cover in the South, or (2) greater mean elevations above mean sea level in the North.

However, limitations of the satellite retrievals should also be kept in mind. First, the method is relatively insensitive to extinctions by pollutants in the lower troposphere (e.g., aerosols and ozone) that are more prevalent in the Northern Hemisphere. However, in the context of the evolution of skin color, these differences are not important because they probably developed only recently (e.g., since the Industrial Revolution). Second, very little work has been done so far to validate the satellite estimations of UV radiation, particularly with regard to hemispheric differences. The first CD ROM issued by NASA of UV doses estimated from the TOMS instruments contained errors and has since been revised (Herman et al., 1998). However, the error should not have caused significant systematic differences in derived UV radiation between the hemispheres, so it would not have altered the conclusions of Chaplin and Jablonski. Clearly, more measurements are required at further sites both to validate the satellite estimations and to quantify the latitudinal differences in UV radiation. We further note that if maximum UV levels rather than annual doses are related to skin color, then the clear-sky calculations may be more appropriate.

Chaplin and Jablonski have raised some interesting points. Further work needs to be done to unequivocally establish the causality between latitudinal differences in UV and skin color. Future studies of skin color should include regions at larger latitudes, where hemispheric differences in UV radiation become more pronounced.

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